suitability of active advisories for achieving more accurate final approach spacing.

The aFAST system has used trajectory tracking to control several hours of flights to an airport with a single arrival runway. During these intentionally busy traffic scenarios, the aFAST system achieved safe and precise separation of the aircraft. In the near term, work will focus on the trajectory tracking and advisory tracking methods of testing. These techniques will be used to (1) quantify the aFAST system's sensitivity to prediction and flight technical errors and (2) assess the benefits of active advisories. Finally, preparation for more complex multi-runway scenarios will begin.

Point of Contact: John Robinson
(650) 604-0873,
jerobinson@mail.arc.nasa.gov

An Analysis of the Radar Reflectivity of Aircraft Wake Vortices

Karim R. Shariff

Large aircraft shed strong vortices in their wakes which pose a hazard to following aircraft. Therefore, during landings in bad weather (that is, under instrument flight conditions) strict spacing is maintained between aircraft. These spacings are usually too conservative, and it has been estimated that several billion dollars could be saved annually by the airlines if the spacing could be reduced by 2 kilometers (km) from the current separations of 5.5 to 11 km. The objective of this work was to assess the potential of ground-based radar for detecting the vortices.

What is needed is a wake sensor that is relatively inexpensive, has long range, requires little or no maintenance, and works in all weather conditions. No sensor currently meets these requirements. Because the pressure in the eye of an aircraft vortex is low (and thus has a low index of refraction), the air in the eye reflects radio waves. A scattering analysis revealed that the peak reflectivity occurs at a frequency near 50 megahertz (MHz) (see fig. 1) and is strong enough that a vortex could be detected at a range of 3 km with an average power of about 400 watts. A frequency of 50 MHz has several advantages: (1) clutter from rain and fog is not an issue and so the system would work in all weathers; (2) inexpensive and low-maintenance radars already operate at 50 MHz for measuring atmospheric winds and they could be modified to track vortices; and (3) if the system is supplemented with sound waves to enhance reflectivity (via the so-called Radio Acoustic Sounding System technique), the required sound frequency is low enough that attenuation of the sound wave (which would limit range) is not a problem. The main disadvantage of the system is size of the antenna system. A typical set-up might have a 10 by 10 array of small TV-like antennas spaced 3 meters apart on the ground. Such a system cannot be physically pointed. Rather, phase differences would be utilized for pointing.

A provisional patent has been filed and a flight test is being planned to verify the predicted reflectivity near 50 MHz.

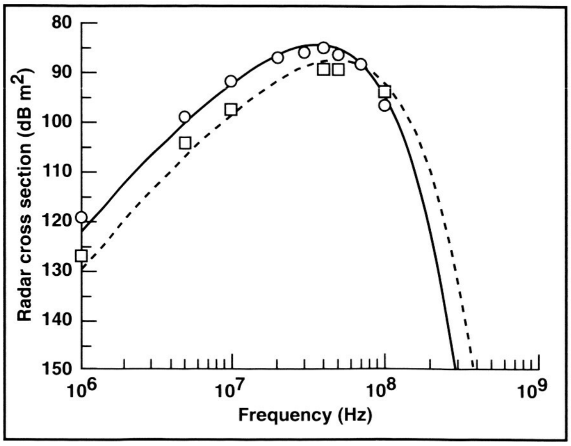

Fig. 1. Predicted radar cross-section (RCS) of aircraft vortices. The symbols show the results of a scattering analysis implemented computationally. The curves show the results of a simple but approximate analytical formula. Solid line and circle symbol: Vortex RCS for B-747 class aircraft. Dotted line and square symbol: Vortex RCS for DC-8 class aircraft. This figure is for a range of 1 km. Note that since aircraft vortices are not a point target, the RCS is a function of range and so the plotted results should not be used for other ranges.

Point of Contact: Karim Shariff
(650) 604-5361
shariff@nas.nasa.gov

Uncertainties in Prediction of Wake-Vortex Locations

Vernon Rossow

The capacity of many of the nation's airports is now limited by procedures that require sufficient separation distances between arrival and departures to prevent a trailing aircraft from encountering the vortex wake of a preceding aircraft. Vortex wakes must be avoided because, during the first few minutes of their duration, they contain intense swirling motions that can cause encountering aircraft to roll uncontrollably, and possibly crash. Considerable research is under way to better predict the location of vortices (shed by the leading aircraft) so that the trailing aircraft can avoid the hazardous region without excessive spacing. The objective of the work at Ames is to determine the principal sources of uncertainty associated with predicting the trailing aircraft's position relative to the vortex wakes being shed by the leading aircraft, and the effect that these uncertainties have on the spacing requirements between the two aircraft.

The primary factors that need to be considered in any computation directed at determining a vortex position relative to a trailing aircraft are (1) the location of the wake-generating aircraft's flightpath, because it establishes the beginning location of the vortex wake; (2) the self-induced descent velocity of the vortex pair; (3) the size and location of the wake-hazardous region; (4) the wind velocity along the flightpath of each aircraft, and its variation with time; and (5) the location of the following aircraft's flightpath. The flightpath of the trailing aircraft must be included, because it is an important factor in determining the probability of an encounter. With the exception of the self-induced descent velocity of the vortex pair, all of these factors contain enough uncertainty to significantly affect the probability of a hazardous encounter for a given set of procedures and spacings for aircraft on arrival or departure at an airport.

Numerical simulation of a wide variety of arrival operations was used to study the effect of these uncertainties on the probability of a wake encounter by a following aircraft. In the study, the size of the hazardous region and the level of uncertainties in the winds along the